Limitations of Internal Protective Devices in COTS Lithium-ion Spinel 18650 Cells

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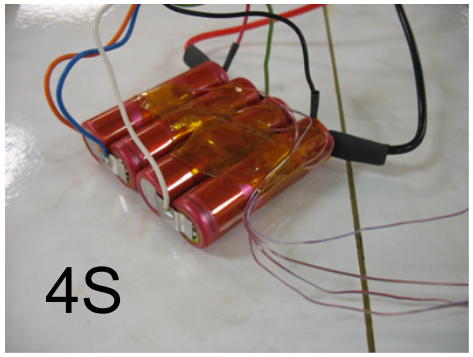
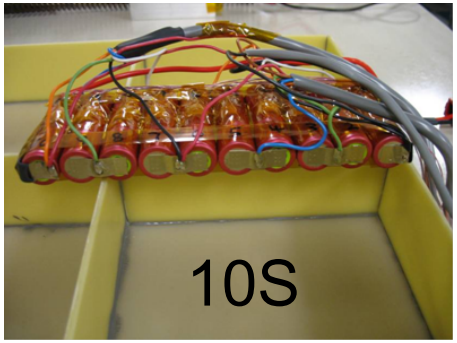
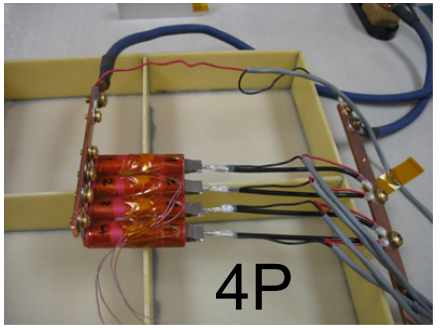
Introduction

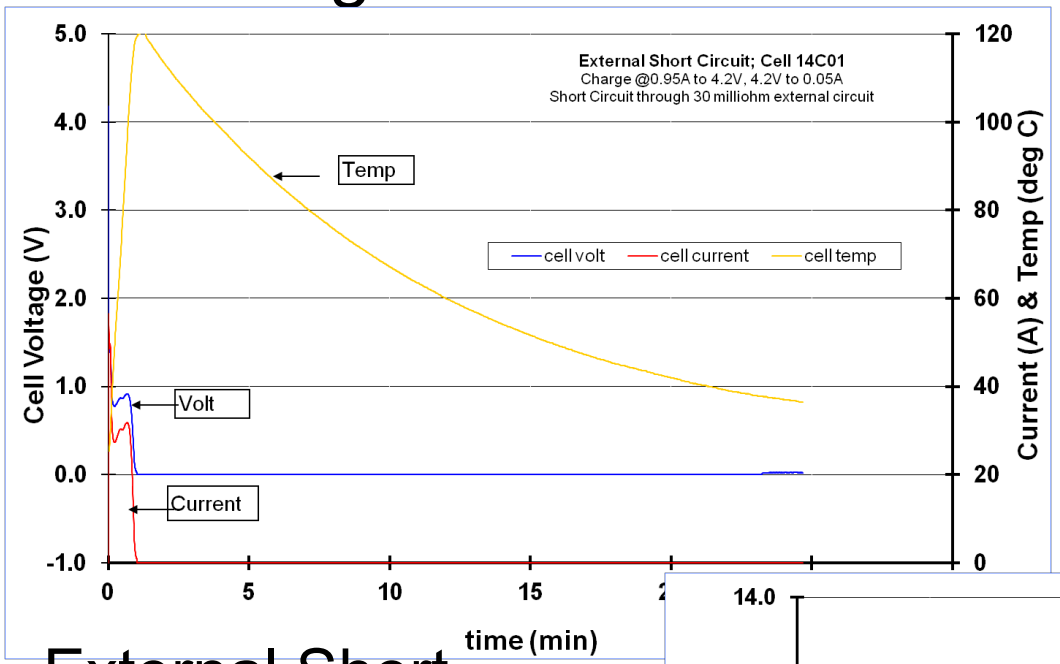
- In the past few years, testing at NASA-JSC has indicated that internal protective devices in small cylindrical COTS (commercial-off-the-shelf) Li-ion cells failed to protect when the battery module designs included multi-cell series and/or parallel configurations.
- Testing carried out was mostly overcharge and external shorts.
- Tests were carried out with cells in series and cells in parallel
- The tests carried out were off-nominal and were carried out under worst-case conditions to determine the worst-case failures that could occur.
- Past tests included determination of PTC (Positive Temperature Coefficient) limitations for cells from different manufacturers, CID (Current Interrupt Device) tests in header assemblies as well as single cells and choice of diode for prevention of catastrophic hazards in multi-cell strings.
- The current test program was carried out on Spinel 18650 li-ion cells to determine the tolerance of cells that have only CIDs and no PTCs.
- Cells used for this test program were only test vehicles to provide data for the issue being discussed and also due to ease of availability. The test results do not infer any type of endorsement and are presented for information purposes only.
- Configurations tested were the following:
  - External Short: Single cells, 4S, 10S, 4P, 10P
  - Overcharge: Single cells, 4S, 10S, 4P, 10P





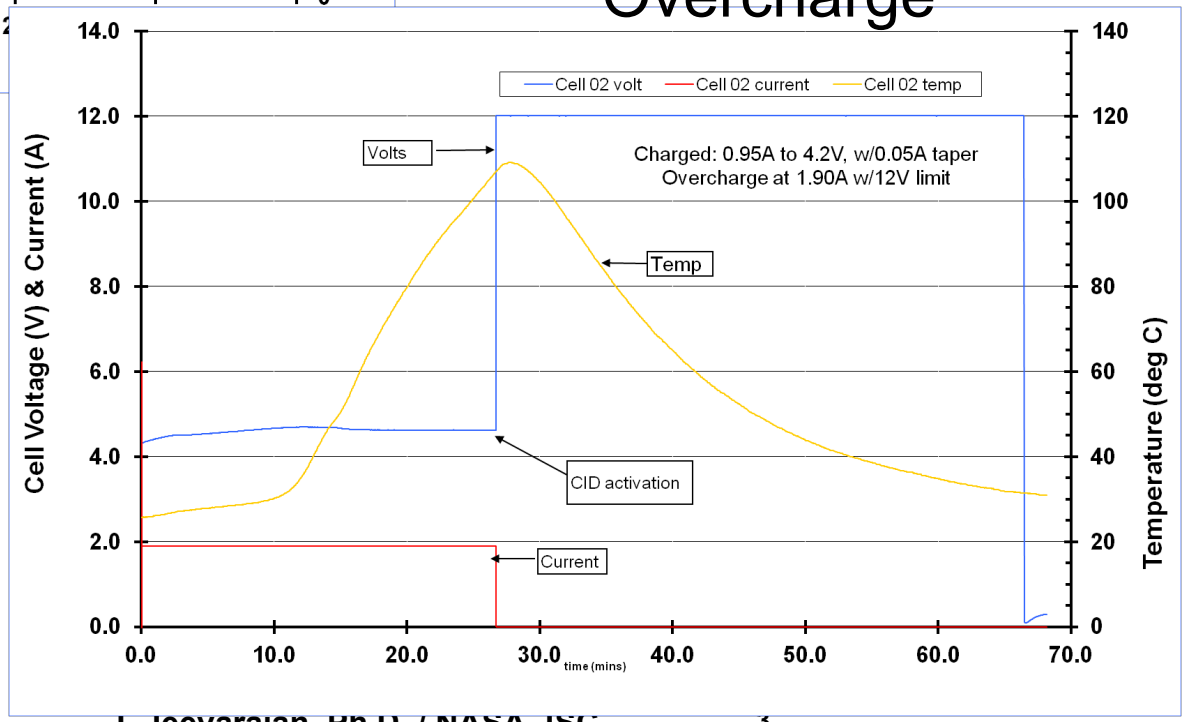


Single Cell External Short and Overcharge

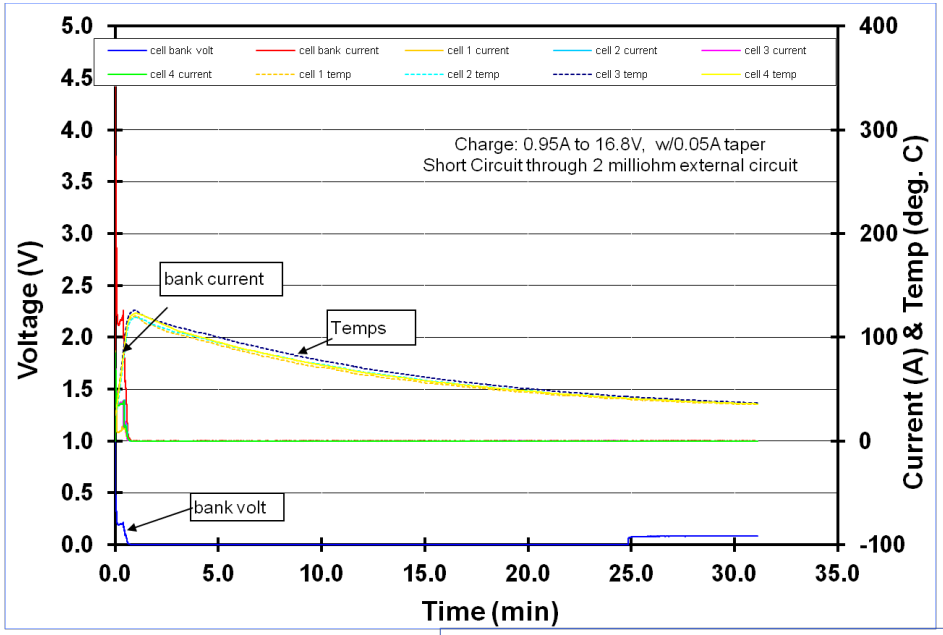


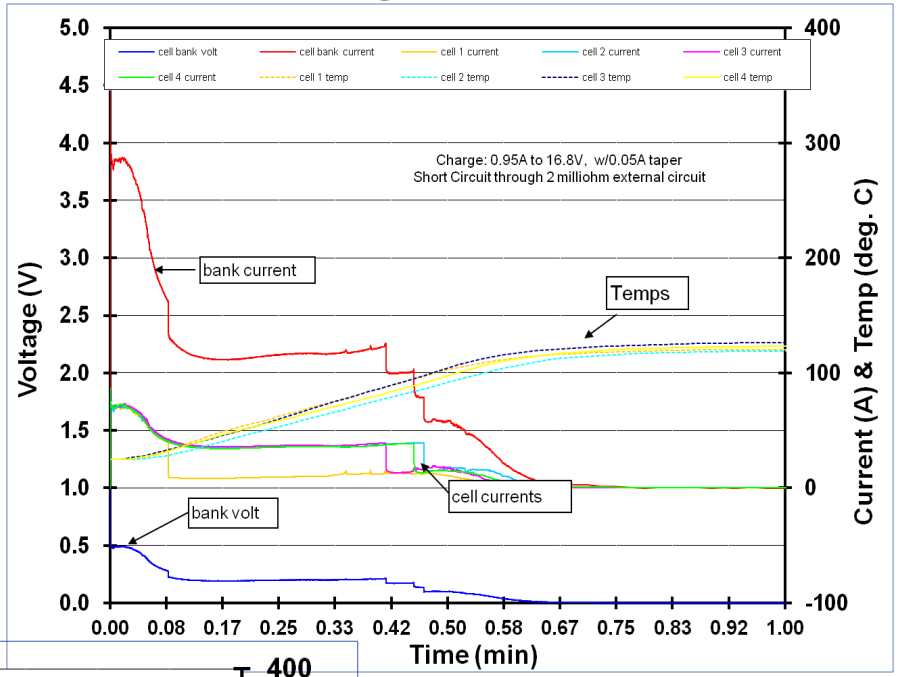
External Short

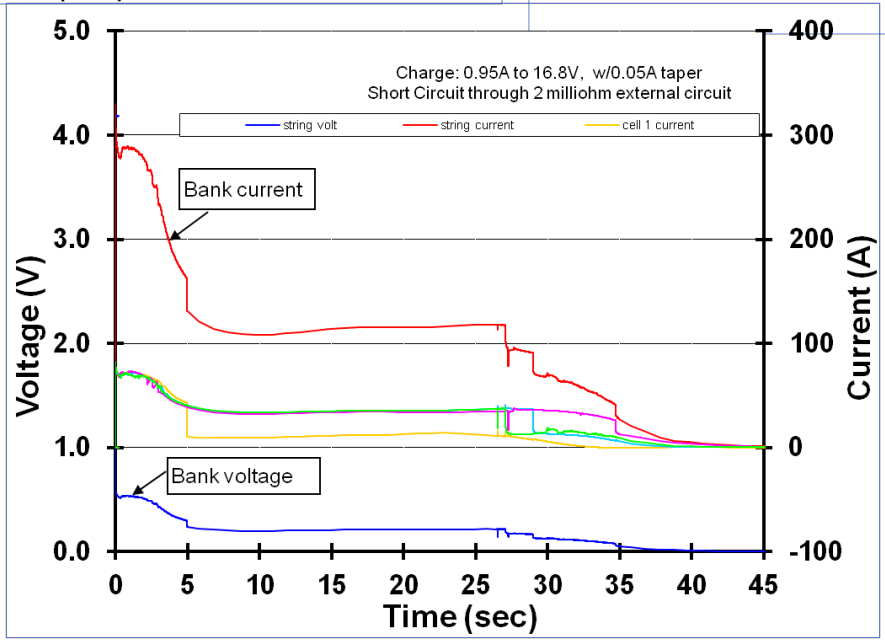
Overcharge



External Short Circuit on 4P Configuration



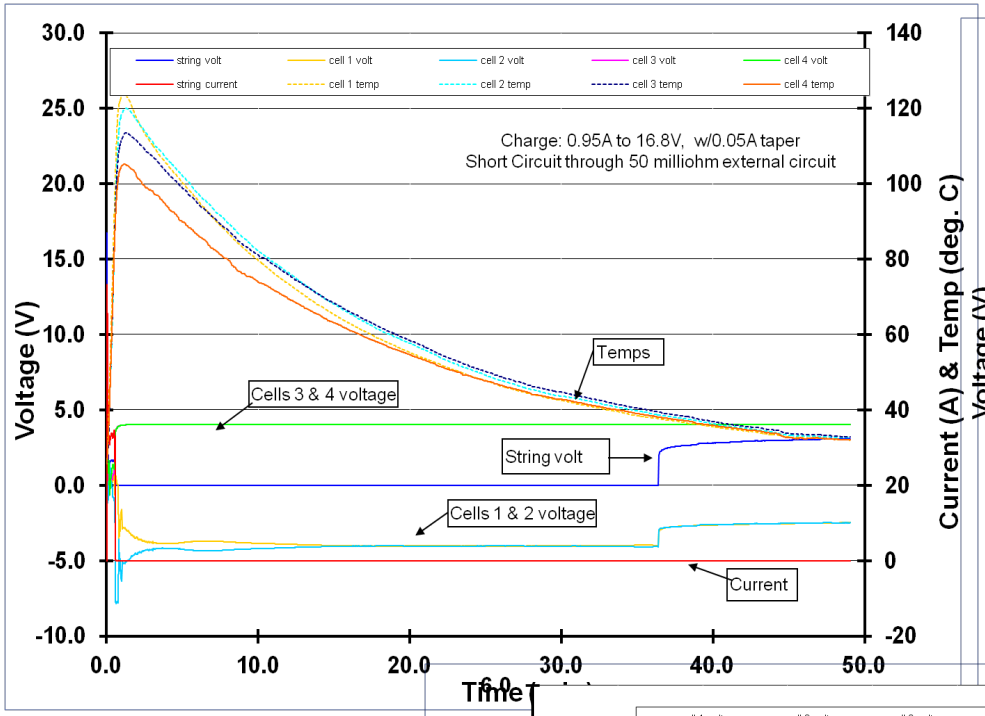


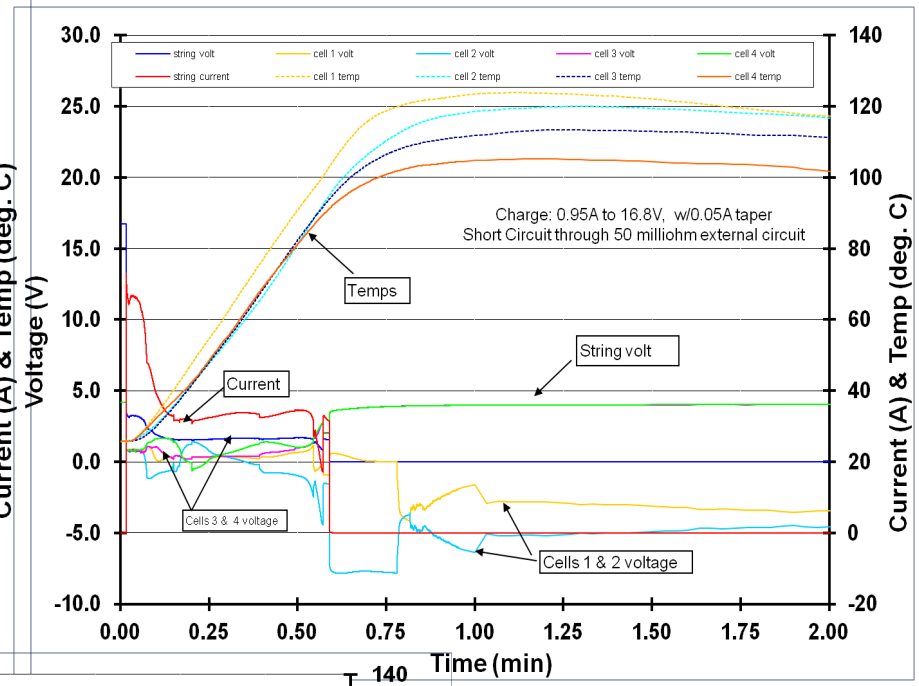


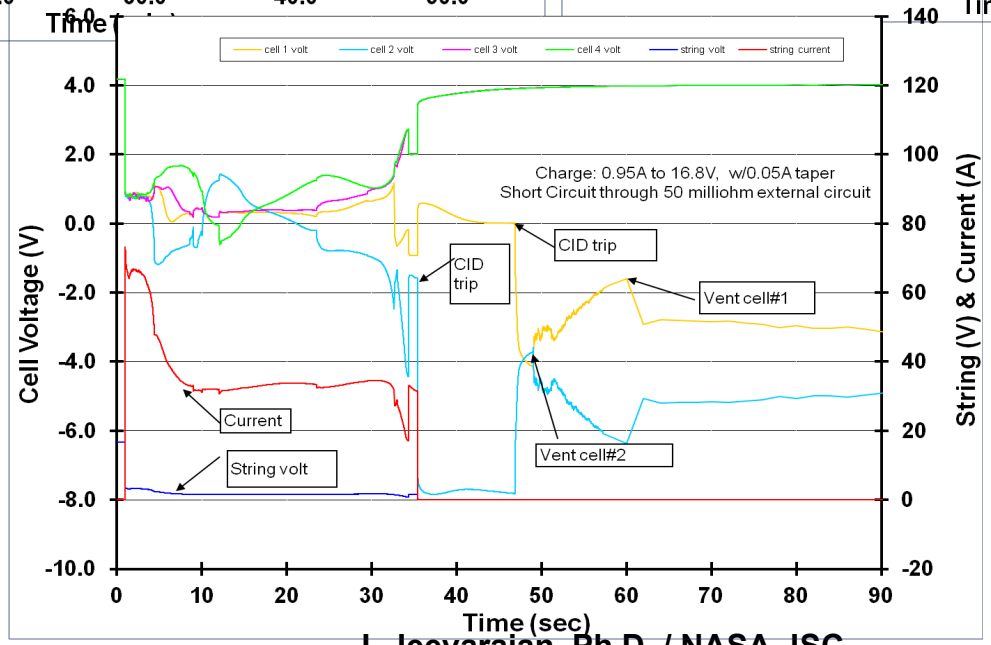
All 4 CIDs tripped and all 4 cells vented; inrush current 360A

video

External Short Circuit on 4S configuration

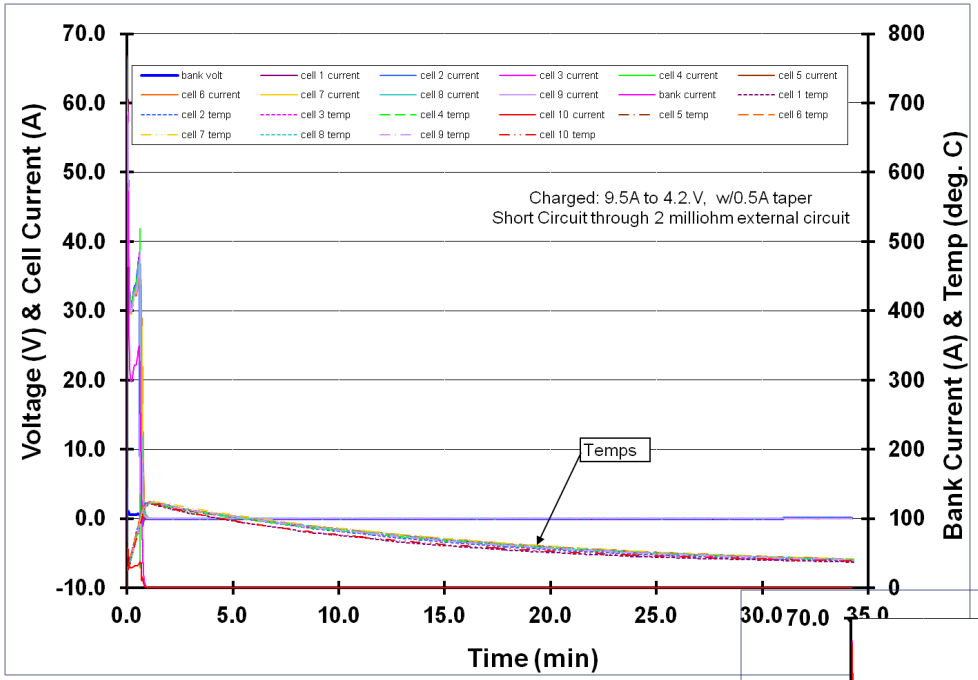






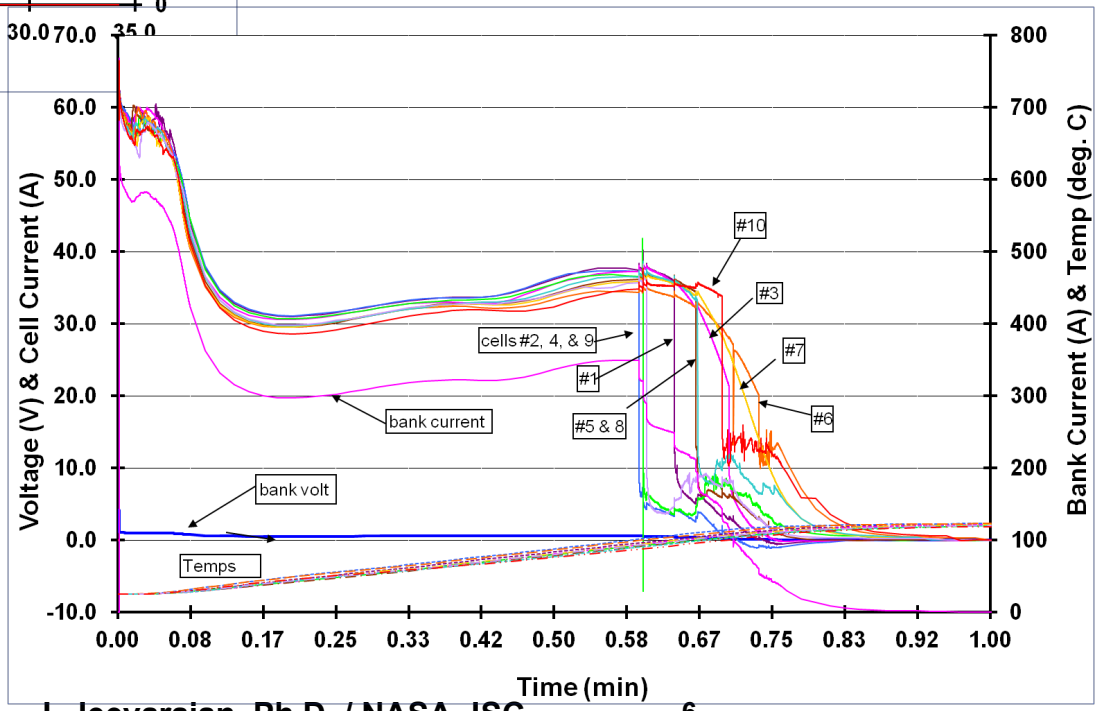
Cells vented

External Short Circuit on 10P Configuration

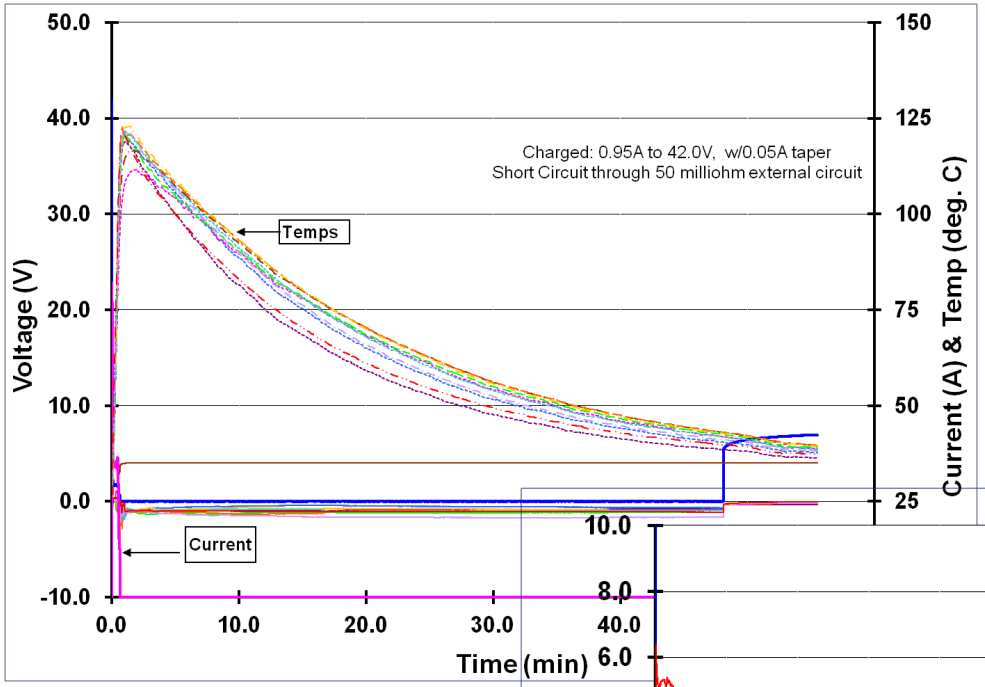


All 10 cells had CIDs tripped all 10 cells vented; inrush current 680 A

video

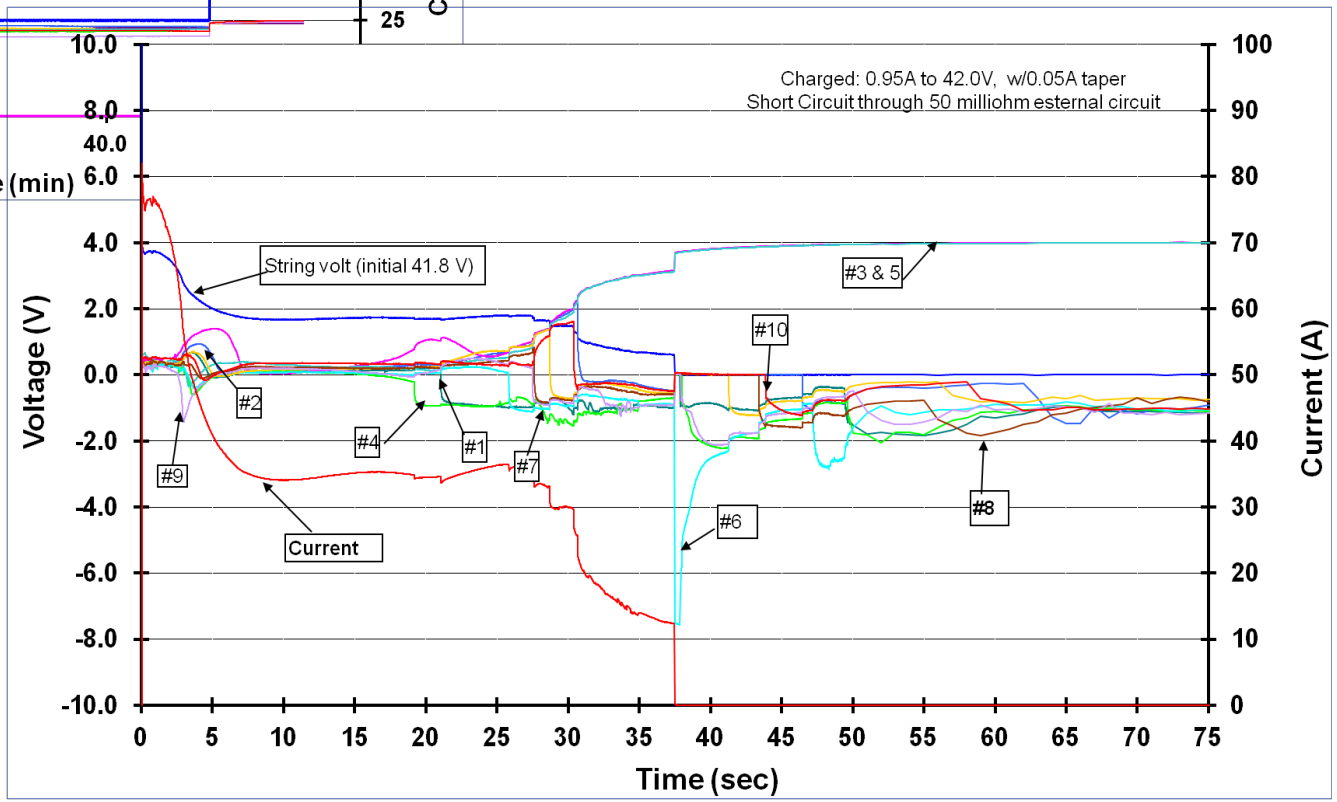


External Short Circuit on 10S configuration

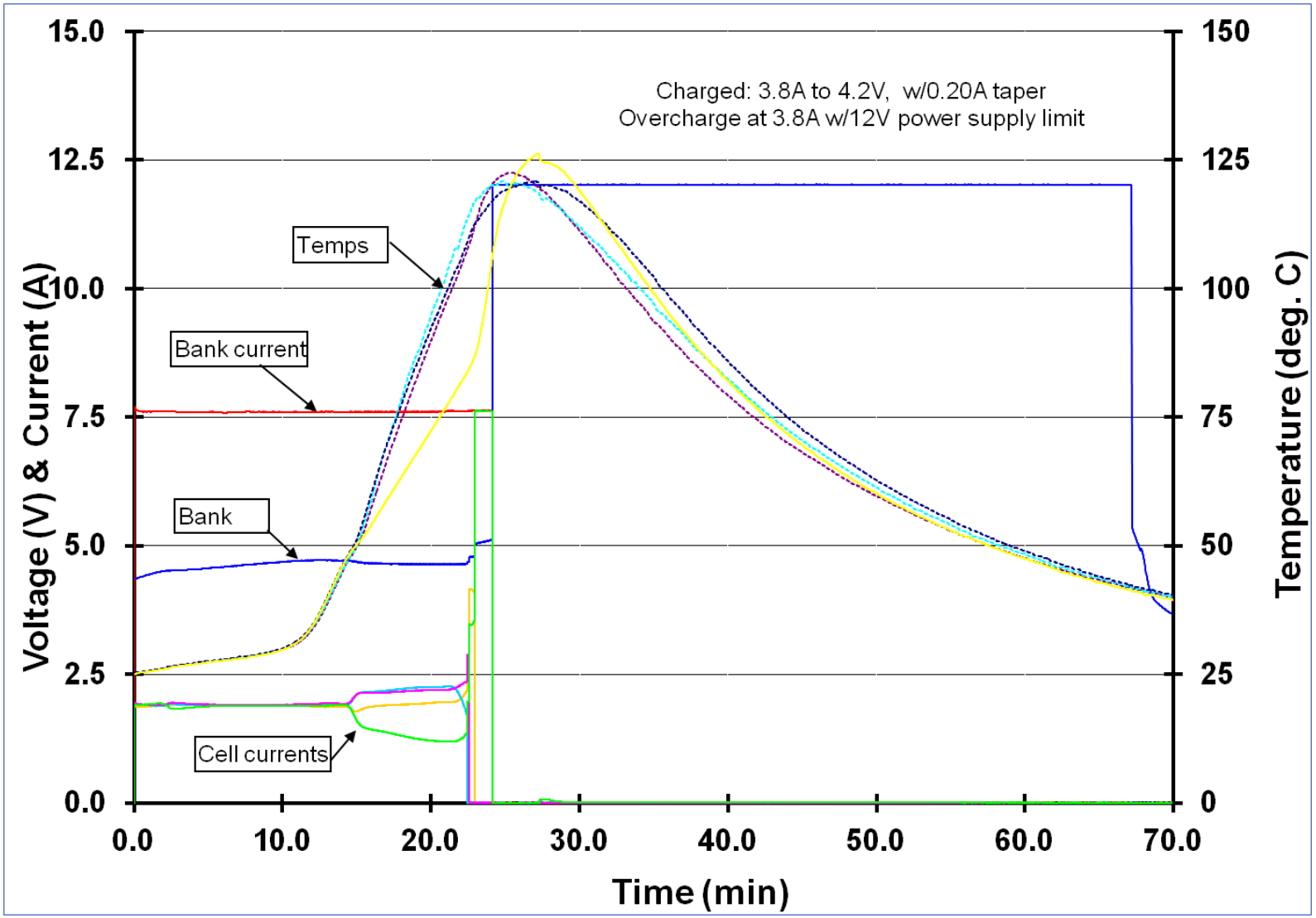


8 Cell CIDs tripped
Vented electrolyte; first cell vent 10 seconds after current dropped to 0 A

video

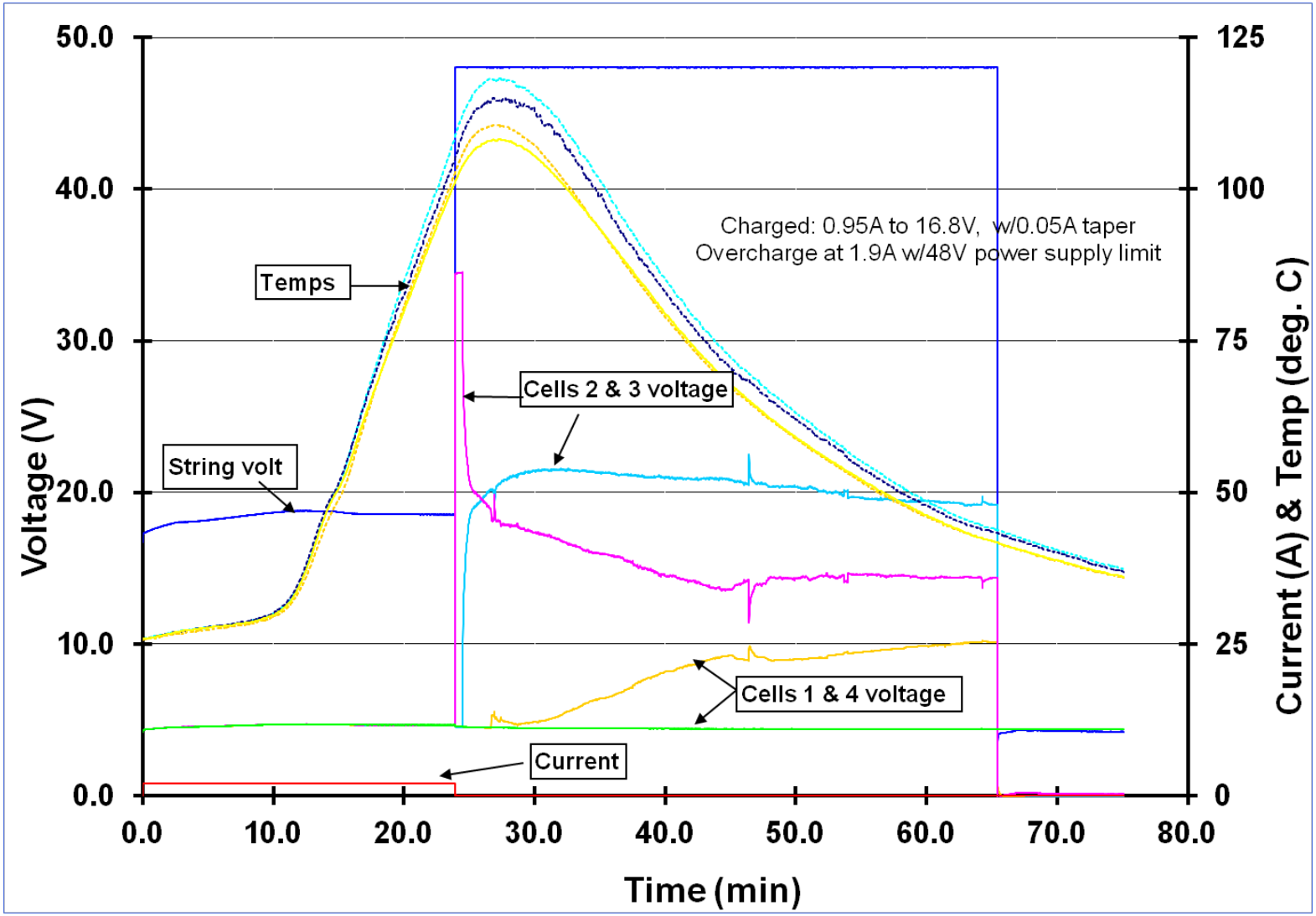


Overcharge Test on 4P configuration



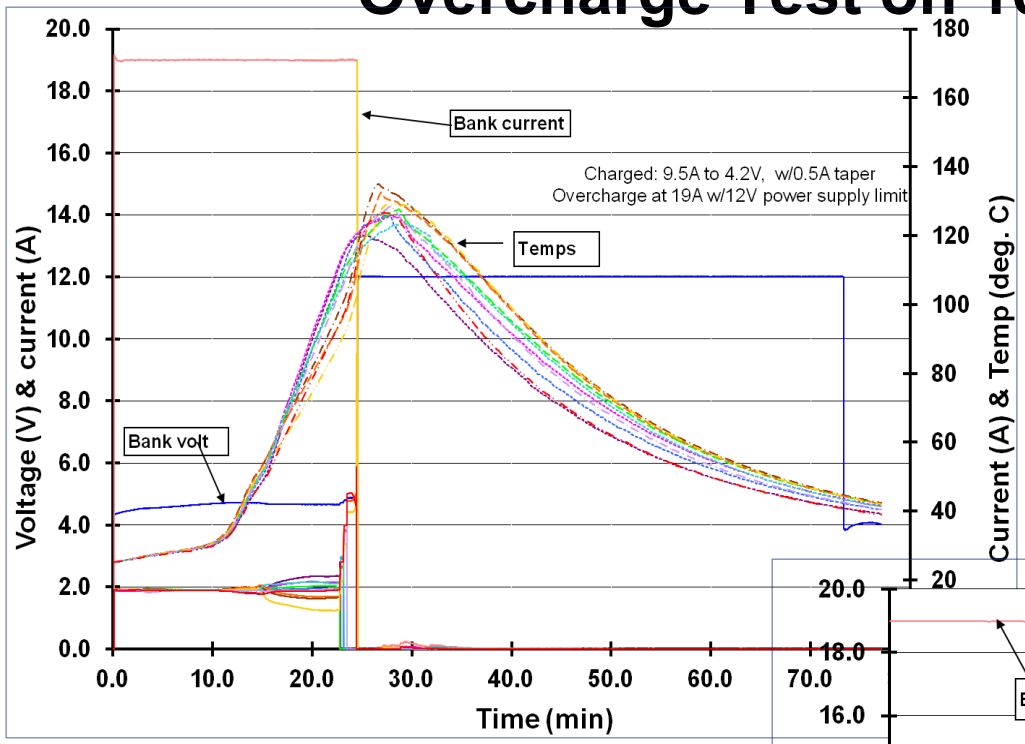
All 4 CIDs tripped, one cell vented

Overcharge Test on 4S Configuration

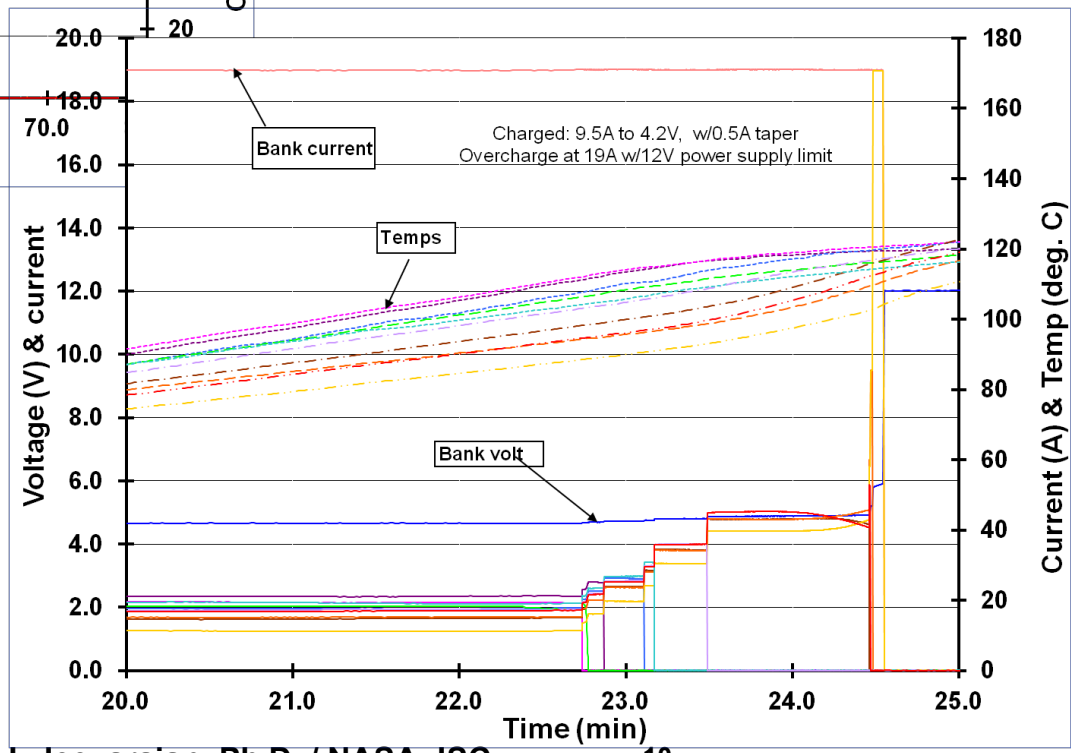


3 CIDs tripped, no venting observed

Overcharge Test on 10P Configuration

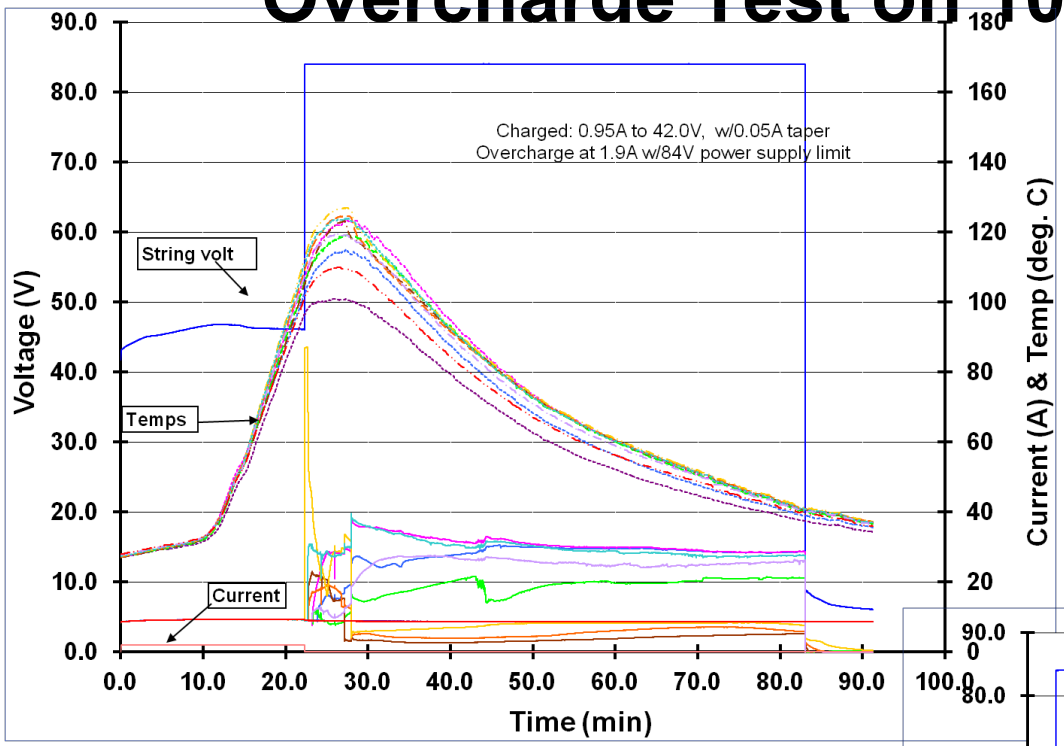


All CIDs tripped
9 of the 10 cells vented

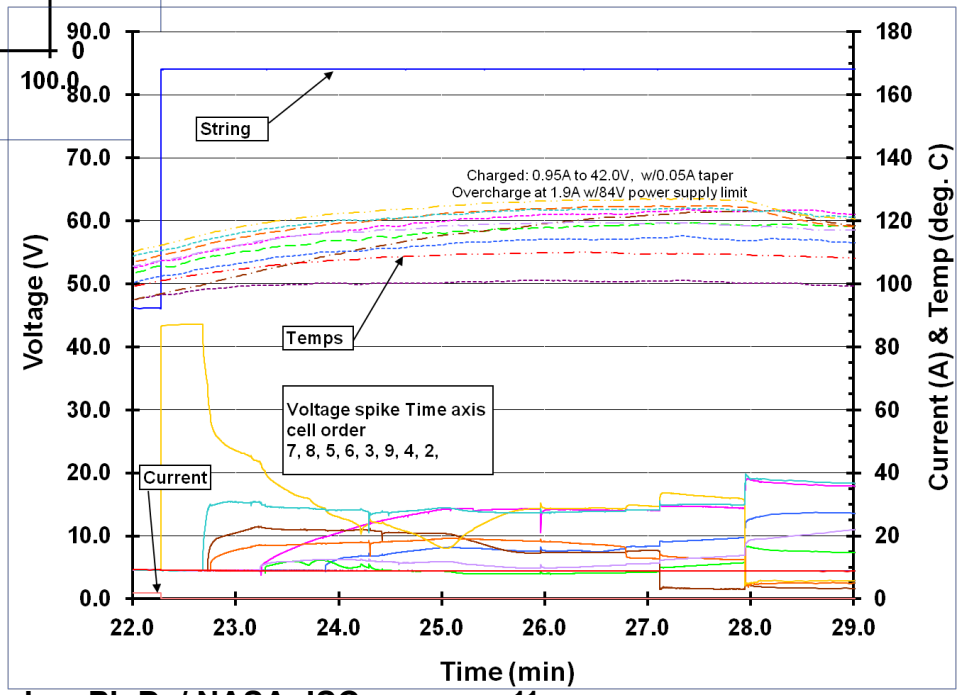


video

Overcharge Test on 10S Configuration



8 CIDs tripped; after current dropped to 0 A three cells vented



Summary and Conclusions

- The CID in spinel cells do not always protect when cells are used in multi-cell modules.
- It was observed that even after the current to the cells is cutoff, the interactions between the cells in the test module is significant and can cause some cells to vent electrolyte and produce gases and smoke.
- The recommendation is to test in the relevant and appropriate configuration to determine and characterize the safe operation of and protection by the CID. Battery designers should be prepared to use additional external current and voltage controls and not completely depend on the CID for operation in multi-cell modules.
- Fires were not observed but the presence of high temperatures and the venting of flammable electrolyte could easily trigger the occurrence of fires (combustion of electrolyte and /or vapors) depending on the battery module configuration (picket fence type configuration in current tests have better heat dissipation than nested configurations that were not tested under the current test program).

Acknowledgment

SRI for carrying out this work.